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Remobilisation of a parabolic dune in Kennemerland, the Netherlands

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Introduction

Large parts of the Dutch coastal dunes consist of parabolic dunes, which developed in episodes between 800 and 1850 AD. It is not clear yet which conditions were responsible for the sudden development of these dunes. Klijn (1990) argues that coastal erosion of the barrier landscape, induced by sea level rise and increased storminess must be the main cause of the massive input of sand and subsequent transgressive dune formation. Due to stabilizing activities, but possibly also to climate change, all these dunes were stabilized in the past two hundred years. At present, aeolian activity in the coastal dunes is restricted to small-scale features like blowouts.

Parabolic dunes are believed to be features in a transitional landscape between mobility (transgressive dunes) and stability (vegetated dunes). Several authors describe transitions from stability to mobility and reverse due to human influence (grazing, sod and wood cutting; planting) and/or climate change (decreased/increased precipitation, increased/decreased windiness). Anthonsen et al. (1996) describe the transition of a dune in Denmark (Råbjerg Mile) from crescentic to parabolic, probably due to minor climate changes. Hesp (in press) describes transitions from parabolic dunes to transgressive dunes and vice versa in New Zealand, due to human activity. Tsoar and Blumberg (in press) ascribe the transition from barchanoid to parabolic dunes in Israel to a decrease of human pressure.

In the Netherlands several experiments are carried out to restore aeolian dynamics. In 1998 a complex parabolic dune in the Kennemerduinen, The Netherlands, was remobilised by removing vegetation (pine forest) and soil. The aim of the experiment is to investigate whether large-scale dunes can be mobile in the present climate and measures like these are successful for durable dune management, ensuring periodic rejuvenation of the landscape by natural processes.

Figure 1. Upwind side of the devegetated crest (left) and downwind side (right)

Figure 1 illustrates the dune, two years after the reactivation. The system represents two different situations. The northern part consists of a 150 m wide parabolic shape, which was completely devegetated, including crest and slipface (Figure 1). The southern part consists of a narrower, 50 m wide parabolic shape, of which only the stoss slope was devegetated. This paper discusses some of the results and the differences in development for these two situations.

Methods

Each month erosion and deposition is measured using erosion pins. These are established in 5 transects and on several significant places over the area. Absolute heights of the erosion pins and transects are measured with a lasertheodolite and with GPS equipment yearly. Results give insight in slope development and rates of processes. In 1999 and 2001, aerial photographs at a scale of 1:2500 were taken of the area. These were used to map vegetation establishment, activity of processes and geomorphological development. Wind data of the Royal Meteorological Office are used to get insight in the wind energy and to compare this to 'average' wind conditions.

Results

Wind data (KNMI, 2000; 2001) reveal that since the start of the experiment storminess was less than average. Yearly rainfall was considerably more than average, with total amounts of around 1000 mm in 1999, 2000 and 2001. Despite these 'unfavourable' conditions for sand transport, considerable changes occurred in the area and large volumes of sand were transported.

In the deflation plane most of the surface is erosive, although locally the surface has reached the groundwater table and vegetation is beginning to establish (mainly *Ammophila arenaria* in clumps, *Carex arenaria* and mosses, *Bryum spec.*, *Juncus articulatus*, *J. alpino-articulatus*, *Carex trinervis*). The average vegetation cover is less than 10%, but on the trailing ridges vegetation cover is increasing up to 50%. Cross sections 1 and 2, which cross the deflation plane, show mainly erosion, with a maximum of 0.33 m between 24/09/99 and 12/12/01.

The presence of a large, bare deflation plane in front of the dune results in a large input of sand onto the dune. Partly this is deposited in front of the dune, partly on the lee face, and, in the devegetated case, partly several 10s of meters behind the back of the dune.

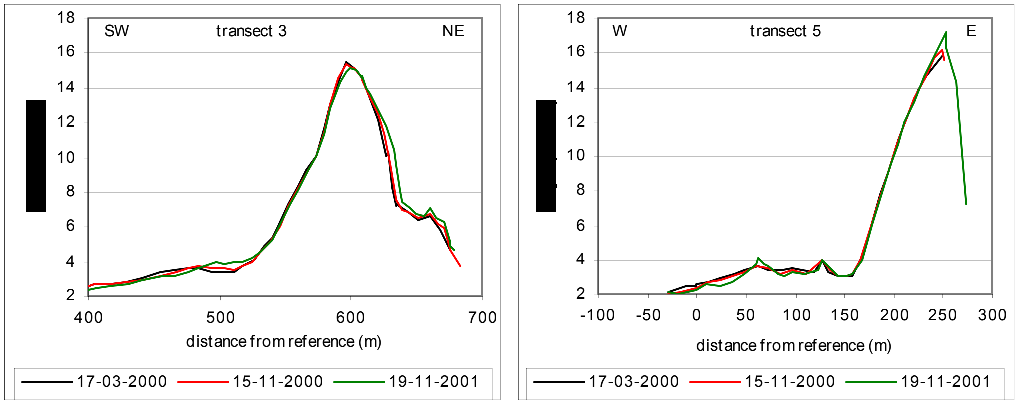

Figure 2. Profile development for the northern (2a, left) and southern (2b, right) part

In the completely devegetated case, the (bare) crest is eroding, while deposition takes place in front of the dune and at the back (Figure 2a). A maximum erosion of 2.55 m on the crest was recorded since the start of the experiment, with an average of 0.93 m, measured over 8 pins. The crest is irregular and several small blowouts have been developing. Because of the blowouts in the crest and 3-dimensional flow around the back of the dune, no clear slipface is developing. The characteristics of the dune change from parabolic into transgressive, dome shaped. Parts of the crest are still covered with old roots, which may reduce the erosion of the crest. There is hardly any vegetation development on the crest.

In the partly devegetated part, the crest has grown more than 1 m because of deposition in the vegetation on top (Figure 2b). The shape of the dune is more isolated and comparable to a large trough blowout. The lee slope is a clear slipface. Most of the sand that passes the crest is deposited on the slipface. Only during very strong winds, sand is moving in suspension (jettation, see Arens et al., in press) and is deposited in the vegetation further downwind. Apparently most of the sand that accumulates on the slipface is derived from the deflation plane. The slope has not changed, and mainly acts as a transport slope, over which sand that is eroded from the deflation plane is transported and finally deposited on the crest and in the slipface.

Figure 3 shows the mobility of the crest line and the (toe of the) leeface. The leeface moved between 5-12 m (northern part) and 0-7 m (southern part) in the period April 1999 to July 2001. From profile 3 it appears that the displacement of the crest and slipface is 2.5 m respectively 4.3 m between November 2000 and November 2001.

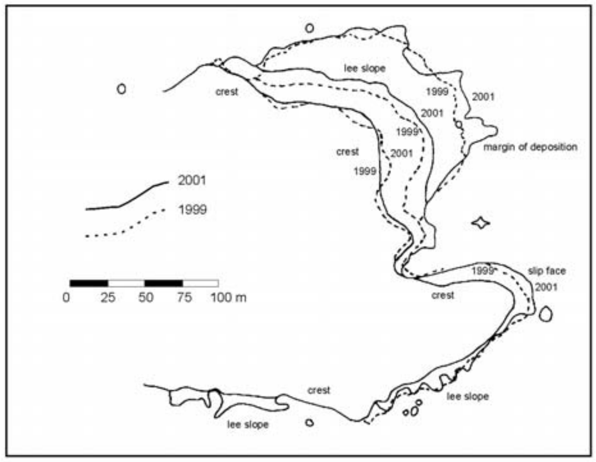

Figure 3. Mobility of crest and slipface

Discussion

Large-scale dynamics are possible in the present climate in the Netherlands, even when conditions are less windy and more rainy than average. The relatively limited extent of dynamic features in the Dutch coastal dunes is obviously related to the stabilising efforts of human beings. However, it is likely that also the large-scale dynamics in the past were the result of human action (see Hesp, in press), although Klijn (1990) argues that this cannot be the sole explanation for the large-scale mobility these dunes experienced in the past.

The parabolic dune adapts to a new situation. The dune probably developed in a situation with a vegetated deflation plane and a crest covered with marram. Most of the transport (erosion) probably occurred on the windward slope and sand was mainly deposited on the crest. Consequently the slope was steep and concave. In the new situation, with a large source of sand, and limited vegetation growth, the dune transforms into a transgressive dune, with a long and smooth stoss slope. Probably, the crest erodes until the ratio between stoss slope length and height is in equilibrium.

In a dune landscape, mobility is governed by sand supply (availability), wind energy and vegetation characteristics (e.g. Nishimori and Tanaka, 2001). There is some threshold for transition from mobile to stable dunes and the reverse. Apparently, this threshold reflects a range of conditions, in which parabolic dunes are characteristic features. Depending on local variations, particular spots are mobile or stable. Thus, in one and the same landscape, small-scale transgressive dunes, parabolic dunes and stabilised dunes can coexist.

Conclusions

The results prove that large-scale aeolian dynamics can be restored in the Netherlands, by removal of vegetation and soil, even with the limited wind energy and the relatively large amounts of rainfall that we experienced in the last 3 years. The type of dune that develops depends on the presence and growing capacity of vegetation. Based on three years of measurements, our preliminary conclusion is that within the same area, dune types where sand transport dominates over vegetation and dune types where vegetation dominated over sand transport can coexist.

The local configuration is important for the type of slope that develops: concave, eroding slopes when there is no upwind sand source, and long, aerodynamically adapted slopes with an upwind source.

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